warmer than the mountain summit. Various circumstances are adduced to support the result, and the explanation is sought in the suggestion that the air flowing from the sea over the mountain would be mechanically raised and practically subject to the adiabatic gradient which is not reached in the free air. The consideration of the relative heights of clouds as observed on the hillsides and over the sea is adduced in corroboration.

A CURIOUS COINCIDENCE. IS IT ACCIDENTAL OR GOVERNED BY LAW?

By Mr. G. N. SALISBURY, Section Director, Seattle, Wash.

Two or three years ago the writer noticed in the annual precipitation totals of the Seattle station a certain apparent recurrence or periodicity in groups or series of three, and looked forward with much interest to see whether it would longer continue. It was found that the light rainfall of 1901 filled the conditions of the recurrence, and the writer concluded that, in accordance with the series, the year 1902, as a whole, should be one of maximum precipitation. Therefore, even during the long dry spell of last summer and autumn, he never lost confidence that the deficiency in precipitation would be made up. That the confidence was justified was seen in the heavy rainfall of November and December, while the total precipitation for 1902 was 45.78 inches, the greatest amount since the beginning of the rainfall record at Seattle.

To illustrate more clearly what is meant, the total annual rainfalls at Seattle are given in their order, beginning with 1892: *31.32*, 45.16, 41.08, *29.69*, 42.83, 41.53, *29.28*, 37.13, 36.43, *30.18*, 45.78. A striking peculiarity may at once be recognized in the above figures, viz: beginning with 1892, every third year appears to be one of minimum rainfall, thus: 1892, 31.32; 1895, 29.69; 1898, 29.28; 1901, 30.18. Also every third year beginning with 1893 appears to be a maximum, thus: 1893, 45.16; 1896, 42.83; 1899, 37.13; 1902, 45.78. Representing the minimum values by *c*, the maximum values by *a*, and the intermediate values by *b*, there results a recurring cycle or series like this: *c..a..b..c..a..b..c..a..b..c..a..* The records for 1890 and 1891 are incomplete, but judging from the record of Madrone, which is a near-by station, the year 1890 would be an *a* year and the year 1891 a *b* year, thus further extending the series.

Curiosity was naturally aroused to see if the same apparent 3-year cycle could be detected at other stations, and investigation revealed that at all stations throughout the State, so far as observations were complete, the same 3-year recurrence had obtained since 1890. As far as the investigation was pursued the same was found true in Oregon, Idaho, and extreme northern California.

This is certainly an interesting coincidence, if nothing more, and the question arises: "Is it an accidental one merely or is it one due to imperfectly understood cosmical causes, which may vary the track of precipitation-producing storms from year to year throughout a certain well-defined fluctuation, so that they return every third year to nearly the same position?"

Unless the records should show a similar recurrence extending back indefinitely we must conclude either (1) that the recurrence is wholly accidental or (2) that a new era has begun in the distribution of precipitation within recent years. In view of our well-established confidence in the constancy and permanence of natural phenomena, the latter conclusion is improbable. The former would be legitimate if there was sufficient past evidence, in the shape of records that could be relied upon. But unfortunately it is only within the past ten years that a considerable number of regular and reliable records of rainfall have been kept in this State. At only a few stations, viz: Spokane, Walla Walla, Vancouver, etc., does the record extend back as far as 1880. For the past twenty-five years at Madrone the third year has always been one of minimum precipitation; but previous to 1890, the order of recurrence of the three years is reversed every cycle, so that we have such a series as: *a..b..c..b..a..c..a..b..c..b..a..c..a..b..c*, etc.

That the annual rainfall should be arranged in a 3-year period in the order a..b..c..for twelve years over the whole State is a remarkable coincidence, even if accidental, but that the recurrence should continue for twenty-five years, or over eight complete 3-year cycles, even at a single station, suggests that there may be a pronounced physical cause. The writer does not insist that it is anything more than a single coincidence, being aware that meteorologists have long ago decided that such a thing as a regular cycle in precipitation need hardly be looked for. The coincidence, however, is so suggestive as to make one ardently wish that the rainfall records of Washington and other Northwestern States, prior to 1890, were not so few, irregular, or unreliable. It is also an incentive to the public spirited voluntary observer to continue his valuable records, showing, as it does, how important his records are as data in the solution of vital climatic problems.

A further interesting coincidence is the correlation of the annual mean barometer with the apparent rainfall cycles. During the past twelve years at the Weather Bureau stations of Washington, Oregon, and Idaho, viz: Seattle, Spokane, Walla Walla, Boise, Pocatello, Baker City, Portland, and Roseburg, the third year of minimum rainfall has invariably coincided with a year of maximum annual mean barometer. The years of maximum rainfall have also coincided with years of minimum mean barometric pressure. A coincidence of maximum rainfall with low barometer and of minimum rainfall with high barometer, is in accordance with meteorological principles and might be naturally expected. But that it should continue throughout the calendar year, and also be in cycles of three, strengthens the suspicion that there may be something more than accident in the coincidence.

CLIMATOLOGY OF COSTA RICA.

Communicated by Mr. H. PITTIER, Director, Physical Geographic Institute.

[For tables see the last page of this REVIEW preceding the charts.]

Notes on the weather.—On the Pacific slope the drought continued up to the 8th, when the rain was general all over the country. The amount of rain for this month and also the duration of same have been without exception in excess over previous years. In San José temperature, pressure, and relative humidity have been about normal; rainfall, 371 millimeters against 230 millimeters, mean for 1889–1900; sunshine, 193 hours against 165 hours, with rather cloudy afternoons. On the Atlantic slope the rainfall was generally less than the normal.

Notes on earthquakes.—May 3, 3^h 36^m a. m., light shock E–W, intensity III, duration 10 seconds. May 14, 6^h 16^m a. m., very slight shock NW–SE., intensity II, duration 4 seconds. May 27, Tres Rios reports one strong shock followed by another, rather protracted, not felt in Jan José. May 28, 2^h 03^m a. m., rather strong shock E–W, intensity IV, duration 6 seconds, reported also from San Isidro Alajuela. May 29, 11^h 47^m p. m., light shock NW–SE, intensity II, duration 3 seconds.

ATMOSPHERIC ELECTRICITY CONSIDERED FROM THE STANDPOINT OF THE THEORY OF ELECTRONS.[1]

By Prof. HERMANN EBERT of the University at Munich.

Recent investigations into the composition of the air, which we already thought we knew so well, have revealed to us a number of new constituents among which the monatomic noble gases discovered by W. Ramsay, and more especially the so-called atmospheric ions or electrons of Elster and Geitel, appeal

[1] A lecture delivered before the eighty-fifth session of the Swiss Society of Natural Sciences, Geneva, 1902, and translated from the Meteorologische Zeitschrift, Bd. 20, 1903, pp. 107–114, by Dr. C. Abbe, Jr.

to the interest of a larger circle of students. The other constituents are in themselves electrically indifferent, as far as at present known, but the last named are distinguished by the fact that they are electrically charged; consequently these react very decidedly upon the forces that proceed from an electric body, whereas the electrically neutral bodies do not do so. The charges on these little particles are apparently neither chosen at will nor accidental, but are of a definite strength for each. From Faraday's law of electrolysis, according to which a definite amount of electricity always seems to be united to a chemically equivalent mass of matter, Helmholtz had already concluded that electricity must be conceived of as consisting of the smallest indivisible electrical quantities or elemental quantities. If one of these elemental quantities occupies the valence position of a material atom or of a combination of atoms, it forms what is called an electric ion. The characteristic of this ion is that by its presence a perfectly definite quantity of ponderable material is attached to a very small but also very definite quantity of electricity (of the order of magnitude 10^{-10} electrostatic units). More recent investigations into discharges through gases and the radiations which accompany them, particularly the studies on the cathode rays, have shown that the electrical elemental quantities also play an important rôle in these processes. The negatively charged particles, of which, for example, the cathode rays consist, have masses that are about 1000 times smaller than the smallest mass of which we have possessed any knowledge up to this time, viz: the hydrogen atom, or according to the investigations of J. J. Thomson, Lorenz, Kaufmann, and Abraham they have only an apparent mass. Since, however, an electric particle moving with great rapidity offers resistance to any change in the direction and velocity of its movements, it must perfectly exhibit the phenomena of inertia. If the characteristic factor belonging to it as a mass be multiplied by the acceleration produced, this product will represent the force required for the change of motion. This factor therefore plays the same rôle as the mass, even if we consider the electric particle itself as being without mass in the usual sense. These electric particles are called electrons to distinguish them from the ions, which latter are formed only after the electrons unite with atoms or combinations of atoms.

It has been possible to establish the presence of these electrons not only inside of the discharging tubes, but also in gases traversed by Röntgen rays, or Becquerel rays, and, according to Lenard, also in such gases as have absorbed the very short waves of ultraviolet light. That they also occur in the ordinary atmosphere of the earth has been demonstrated by Elster and Geitel, by exposing to the air a well insulated electrically charged metallic body, a so-called "dissipator." The loss of charge that occurs from this body can be very considerably increased if a wire cage charged to the same tension with the same kind of electricity be placed about the metallic dissipator and the electroscope.

This increased loss can not be explained by the action of dust, smoke, or moisture, but is only intelligible on the assumption that electrons of the opposite sign are attracted by the wire cage and are used up by the activity of the inclosed dissipator. Since the active surface of the cage is much greater than that of the object within it, therefore the latter will be discharged much more quickly than if the discharge took place without any cage; a conclusion fully borne out by the observed facts. Moreover, negatively laden wires hung in the open air acquire the induced radio activities so characteristic of the gases that have been excited by Becquerel rays, i. e., they become good electrical conductors and are provided with electrons.

In order to measure the charge of electrons contained in the air at a given time and place, the lecturer [Professor Ebert] had constructed an apparatus, which he exhibited. In this apparatus a clockwork aspirator draws a definite quantity of air through the space between two coaxial metal cylinders fitting one into the other; the inner cylinder rests directly upon the electroscope, while the outer one serves as a protecting cylinder. If the capacity of the system and the quantity of air drawn through it in a given time is known, then one can (from the number of volts indicating the loss in tension during this time, after applying a small correction) calculate in absolute measure, the quantity of electricity that has been contained in a cubic meter of air as a charge of electrons. The apparatus is to a high degree free from the influence of the wind and of external electrical forces.

The very first determinations showed that the charges of electrons found at the surface of the earth were conditioned by the changes going on in the higher strata of the atmosphere and the circulatory motions occurring in them. Thus during the foehn the charge of electrons was not only absolutely very high, but there also occurred a noteworthy shifting of the normal distribution, showing that many more positive than negative electrons are contained in the air of the foehn. In order to explain these conditions the lecturer had worked up the data obtained by observers in free balloons with the Elster-Geitel atmospheric electrical apparatus, and with his own aspiration apparatus as used with the sounding balloon. Four such series were conducted by Dr. R. Emden who attained heights of over 7200 meters. H. B. De Saussure had already shown the necessity of undertaking electrical measurements in balloons if we are to learn anything about the character of the electrical phenomena of the atmosphere, and it would be most welcome if other countries would join in the simultaneous, international monthly balloon ascensions made from widely separated points in Europe. In fact these ascensions have already explained many points, but as so often happens in the investigation of infinite nature, so here, where one problem is solved a hundred new questions and problems arise. There is always work enough to be done.

The electronic charge, or the number of electrons, generally increases very rapidly with the altitude, so that we may conclude a proportionally very high degree of electrical conductivity for the highest strata; indeed we must assume this if we are to explain such phenomena as the aurora. Perhaps it is the passage of the ultraviolet rays from the sun through these regions that gives rise to the electrons.

In the lower layers of the atmosphere we generally find a preponderance of the positive charges and this is apparently due to the fact that the terrestrial globe is itself negatively charged and therefore attracts the positive electrons, but repels the negative ones. For this reason above mountain summits, where the density of the terrestrial charge attains a particularly high value, there is a preponderating number of positive electrons present; therefore when the foehn blows across the mountain crests it brings with it down into the valleys this upper air, rich in ions and with its excess of positive electrons.

This shifting of the electron content in one direction or the other appears to produce a specific effect upon the human organism. P. Czermak, who has studied this phenomenon in the foehn region at Innsbruck, is disposed to connect this fact with the so-called foehn sickness which attacks sensitive persons and for which up to this time no explanation has been found. In this connection the results of the Monte Rosa expedition for the investigation of the mountain sickness, recently reported on by Caspari, is very interesting. In hollows, caves, and chasms which communicate with the open air, but at the same time harbor a considerable quantity of quiet, stagnating air, the electron content may attain a very high figure; here also, as will be explained later, an outflow of the negative electrons and a constantly increasing rise in the quantity of positive electrons may take place. It is such partially inclosed spaces, passages, etc., that according to the experiences of many mountain guides, are especially apt to give occasion for the complex phenomena of mountain sickness even where altitude or any other peculiarity of the air offers a predisposing cause for this effect. In such a passage on Monte Rosa, notorious for its mountain sickness, Caspari in fact found that the Elster-Geitel dissipator showed an enormously increased charge of electrons.

The theorem that in the higher, purer strata of the atmosphere the charge of electrons is larger than in the lower, is not without exceptions and apparently can not even be considered as of general scope. If in midsummer a high plateau or the southern slope of a mountain range is continuously and strongly illuminated by the sun, rising currents of air form and elevate the air which has for a long time been in contact with the surface of the earth; a system of ascending and descending circulations is established until the distribution of temperature with altitude corresponds to the adiabatic equilibrium. Each time when air comes into contact with the conducting surface of the earth the latter gives off a portion of its electrons to the air and thus the whole stratum of air gradually becomes saturated with them. This we were able to determine very clearly during two summer excursions in June and July, that we made from Munich in the early morning after the sun had, during the previous day, burned scorchingly on our upper Bavarian plateau. During the night the stratum lying immediately next the ground had greatly cooled off so that we did not at first find decreasing temperatures immediately above us, as is generally the case in balloon ascensions, but encountered rising temperatures, i. e., a so-called inversion of temperature. On the other hand, when we entered the stratum of air that had been warmed by the ground on the previous day, and had risen to a higher level, the temperature fell at the rate of about 1° C. per 100 meters of altitude, a rate characteristic of the adiabatic equilibrium. In this stratum we found almost exactly the same electrical conditions of the air as had been recorded with accurately compared instruments on the surface of the earth at various stations on the preceding day. In summer this stratum may attain a height of 2000 meters and even more over the Bavarian table-land.

At and above this elevation, however, the distribution of electrons is not by any means simple enough to permit one, by extrapolating from the values already found, to determine the electrical conductivity prevailing in those regions in which the polar auroral phenomena principally occur and which, according to both older and more recent observations, frequently extend down to our latitudes.[2] Recently the interest of meteorologists has been awakened by the phenomenon of a peculiar stratification which so subdivides the whole column of air above us that the characteristic meteorological elements, especially temperature and amount of aqueous vapor suddenly change their values in passing from one stratum to another. These stratifications are of the greatest importance for the formation of clouds and consequently for climatological conditions. In balloons one can as a rule perceive very clearly when a new stratum is entered; a sudden change in direction and velocity of movement generally accompanies this transition, due to the different direction and velocity of the wind in the new stratum. Now, it is noteworthy that with each entrance into a new stratum there has been observed a sudden change in the electronic charge and also in the proportion in which the positive and the negative charges are mixed in these strata. Therefore just as each stratum is characterized by a certain temperature and moisture so it is also characterized by certain electrical properties which seem to be conditioned chiefly by its origin. Thus, the strata flowing from the Alps are quite differently constituted electrically from the currents flowing toward the mountains.

But balloon investigations into the electronic charge of the higher layers of the atmosphere should be of interest for other very different reasons also. According to the profound investigations of C. T. R. Wilson it can no longer be doubted that the electrons existing in the air play an important part in all processes of atmospheric condensation. By repeated alternate condensations and expansions of air saturated with water vapor and contained in a large closed space, Wilson freed the air of dust, since the fine particles of the latter serve as centers of condensation and sink with the cloud of mist which forms. Even after this clarification, however, renewed condensation occurred when the supersaturation by the aqueous vapor reached either one of two well-defined limits. It further appeared that these limits were the same and were much more distinctly marked if the inclosed sample of air were artificially ionised by Röntgen, Becquerel, or ultraviolet rays, and that it is *the electrons themselves* which serve as centers of condensation. Of special importance is the fact that the aqueous vapor condenses more readily, i. e., at a lower degree of supersaturation, upon the negative than upon the positive electrons, and consequently that during progressive condensation, first the negative and then the positive particles are precipitated. Recent meteorological investigations have shown that extensive supersaturations are not rare, even in the free atmosphere; therefore the charge of free electrons present in a layer of air in which condensation has just begun must be of great importance in the formation of clouds in that stratum. We must conclude that three classes of nuclei for condensation are present in our atmosphere. The first class consists of dust particles upon which the aqueous vapor is precipitated at the least approach to supersaturation; as these water-laden particles fall to the ground they form therefore a precipitation that is electrically neutral. As the result of a further condensation of the aqueous vapor the second class of condensation centers or the negative electrons become nuclei and the precipitation that reaches the earth's surface brings with it negative charges. Only after supersaturation has proceeded very far will positive charges be brought down (by positive electrons) from the higher atmospheric layers. This explains the varying signs of the electric charges which the atmospheric precipitation shows in a rain shower or in a thunderstorm. At first the signs may be electrically neutral in spite of higher electric tensions at the ground. Lenard found electrically neutral particles among those produced in gases by ultraviolet rays; the mist clouds which he generated in air saturated with water vapor by the passage of ultraviolet radiation showed themselves not to be electrically charged, but neutral, as they descended upon a metal plate connected with the electrometer. However, the thorough investigations by Elster and Geitel, into the electrical nature of the atmospheric precipitations which have been carried on with all the precautions so urgently necessary for such experiments when conducted in the open air, have demonstrated beyond all doubt the preponderance of negative charges. For example, when dew forms on a morning following a clear night the number of negative electrons on the earth's surface decreases.

Our own countings of electrons on the ground, as well as in the upper air strata, furnish the data for approaching nearer to the question from the quantitative side also. In the stratum of cumulus clouds, at about 2000 meters above sea level, we have repeatedly found charges of electrons exceeding those on the earth's surface fourfold and even more. At the surface of the earth under our normal weather conditions there are from one to three electrostatic unit charges of free electricity per cubic meter, with somewhat more free positive charges than free negative as already stated. With increasing altitude this unipolarity becomes more and more equalized, and is ac-

[2] Munich is in latitude 48.2° north.—ED.

companied by a simultaneous increase in the absolute amount of the charge; at an altitude of 3 kilometers we have a charge of more than 4 electrostatic units per cubic meter. For example on the basis of the Elster-Geitel determinations of the electrical charges in the atmospheric precipitation, V. Conrad (Wiener Berichte, 111, Abth. IIa. p. 342, 1902.) has computed that the amount of electricity in 1 gram of the water of a cumulus cloud amounts to 1/36 of 10^{-8} of a coulomb. Within a dense cloud in which the vision could penetrate to a distance of only 18 meters, there was according to Conrad's measurement 5 grams of water per cubic meter, consequently an electric charge of about 1/7 of 10^{-8} of a coulomb per gram of water. Now if the above-mentioned value of 4 electrostatic units, or 4/3 of $10^{-9} = 4/30$ of 10^{-8} of a coulomb of negative electricity be assumed as the charge per cubic meter, then even this amount of electricity would suffice to explain quantitatively the observed electricity of precipitation.

In general the process of condensation brings down only a small fraction of the electrons present. Suppose now that we consider that only the negative electrons take part in the precipitation, then these are weighted down by coatings of water and sink down as rain, but according to our measurements about an equal quantity of positive electricity per cubic meter remains behind in the cloud. Now as Conrad has already shown, if, for instance, we suppose a cumulus cloud of spherical form of only 1 kilometer radius to rest with its center 3 kilometers from the earth's surface, then it will by its own internal charge cause a decrease of potential at the earth's surface of about 11,000 volts per meter of vertical distance. Now, such values have been actually observed in thunderstorms at the earth's surface. If we reflect that for such a gradient a point in the air of 500 meters above the earth would show a difference of tension of 5,500,000 volts with respect to the earth, then we find ourselves here brought to consider tensions such as we see relieved by the mightiest electric process of the atmosphere, i. e., the thunderstorm. As early as 1887 Lins[3] had calculated the immense electrical forces called into being when the charges assumed by him to exist in a cloud, were separated by great stretches of space, and showed that sources of energy were here revealed to us, which were more than sufficient to explain the most violent phenomena of thunderstorms. The theory of electrons now gives us, as we have shown, a surprisingly simple explanation of these charges, and our electron traps deliver to us catches whose magnitudes are quite sufficient to explain the phenomena in a quantitative way. And now finally the last problem, the one which offered altogether insurmountable difficulties to all the old theories, begins to gradually become resolvable from the standpoint of the new theory, viz, the problem of the permanent charge of the earth and the existence above it of a field of electrical tension, or the so-called "fine weather electricity."

It was clear even to the earlier observers that the earth's surface always possessed an electric charge relative to the atmosphere, even in typical fine weather, when there was no trace of thunderstorm conditions within a considerable radius. At such times the earth's mass showed itself negatively charged as compared with the surrounding air; only during cloudy, rainy weather inclining to thunderstorm formation, would the sign of the earth's charge occasinally reverse, but even then only for short periods. To explain this electric charge proper to the earth itself the most divergent theories have been suggested, but none of them have been proved satisfactory. The properties of the electrons furnish a wholly new point of view from which the problem appears surprisingly simple. The positive and negative electrons are to be distinguished from one another wherever they occur by the different velocities at which they travel. Under the impulse of a given electrical force the negative electrons are more easily set in motion and they travel much faster than the positive electrons, which seem to be loaded with a greater quantity of inert matter. On the other hand both positive and negative electrons seem to be charged with the same quantities of electricity, which are distinguishable from each other only by their opposite signs. Now if such an electrical particle pass near a conducting surface, such as the earth's surface or that of some conductor in electric contact with the same, then the passing particle induces in the conducting surface a superficial charge of the opposite sign, which attracts the particle to it. This attracting force, which is directly proportional to the square of the charge and inversely proportional to the square of the distance of the particle from the conducting surface, influences both species of electrons in the same way, but the negative are able to respond to the electrical forces more easily and quickly than the positive. Thus, during a unit of time and with equal charges of positive and negative electrons in the air, a larger number of negative than of positive electrons will always reach the conducting surfaces and give up their charges to them. On mountains, tree tops, and similar places this process is of subordinate importance, since on these projections the charges of the negative earth repel the negative electrons and collect, as we have seen above, a preponderating number of positive electrons. There are, however, many spots on the earth's surface where its own charge is without effect in reference to the particles in the air and where, therefore, the inflow of negative electricity can proceed undisturbed. As Elster and Geitel have shown these places are all concavities, particularly those occurring under the leafy roof of the earth's vegetation, which are of the greatest extent, but also the cavities formed by caves, chasms, and fissures. In the latter cases the projecting portions and points form a very perfect electrostatic protection against the electrical field of the earth, which otherwise would hinder the wandering of electricity into the charged ground. We have evidences that the vegetation in particular plays a very important part in the atmospheric electric processes, and that the process above explained is quantitatively sufficient to renew the electric charge of the earth in the manner just described. It is certain that such a renewal of the earth's charge must occur, since the air is not a perfect electric insulator, and the conductivity due to the wandering of the electrons causes a perpetual tendency to equalization of the earth's charge and of the gradient of tension in the atmosphere.

There is still much to be said on the subject of the relation of this latter gradient to the conductivity of the air and the charge of electrons, and there is already a rather extensive collection of observations at hand which opens a series of new and interesting perspectives. A further consideration of this subject on this occasion would lead us too far; but we may rejoice in the fact that in the theory of electrons the processes of atmospheric electricity have acquired a point of view that promises to contribute very much to the solution of problems, some of which are centuries old, and that incites us to the most zealous pursuit of further studies in this much contested field of research.

[3] See Pellat translated by A. G. McAdie, American Meteorological Journal September, 1885, Vol. II, pp. 215-221, and Park Morrill at pp. 438-445 of the same volume.—ED.

ABNORMAL VARIATIONS IN INSOLATION.

By Mr. H. H. KIMBALL, Assistant Editor, dated April 15, 1903.

In the Comptes Rendus, Paris, March 16, 1903. Volume CXXXVI, pp. 713-715, Monsieur Henri Dufour announced that his observations with a Crova actinometer at Lausanne, Switzerland, indicated a diminution in the amount of solar radiation received at the surface of the earth at that place (latitude 46° 33′) in January, February, and March of the present year, as compared with the average of corresponding months for previous years. This is shown in the following table: